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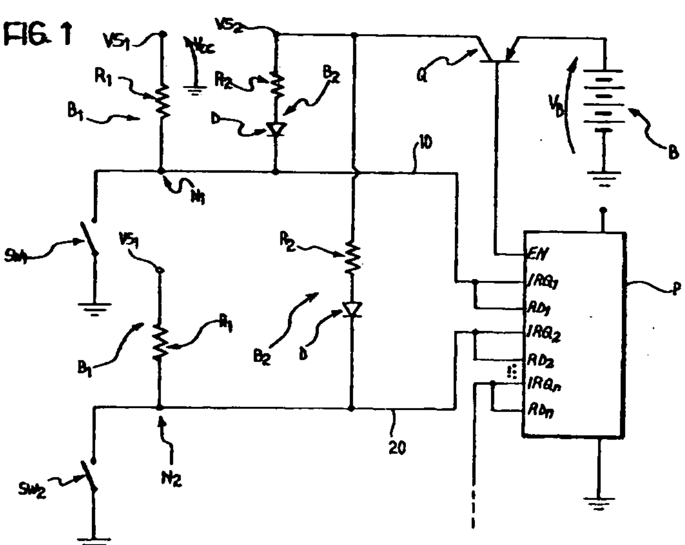
(54) A circuit for detecting the state of electrical switches

(57) A circuit for detecting the state of electrical switches, for example, switches (SW_i) in a motor vehicle, is described and comprises a network (B_1, B_2) which supplies the switches (SWi) and which can produce signals indicative of the operative state of each switch, and a control unit (P) which can correctly interpret the operative states of the switches (SWi). The supply network comprises first and second circuit branches (B_1; B_2) arranged, respectively, for continuously supplying a monitoring current and for selectively supplying a diagnosis current of substantially greater intensity than the monitoring current. The control unit (P) detects and compares the signals indicative of the state of each switch (SWi) which are acquired when the switch is supplied by the monitoring current or by the diagnosis current, and interprets the state of the switch (SWi) from a comparison thereof.

FIG. 1



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Description

[0001] The present invention relates in general to a circuit for detecting the state of electrical switches.

[0002] More specifically, the invention relates to a circuit of the type described in the preamble to Claim 1, for reading the state (open/closed) of electrical switches, particularly for automotive applications, as well as for the diagnosis of a possible damaged condition of the contacts of the switches.

[0003] In a motor vehicle, there are many electrical switches which are used for controlling functions of the vehicle body such as, for example, the opening and closure of the doors (by means of commands to the handles and to the locks) from inside or from outside the vehicle, and in many other control circuits (for example control panels) which may be required to operate at any moment, irrespective of the operating condition of the vehicle (for example, even when the vehicle is at rest).

[0004] Electronic control units provided for managing information connected with the instantaneous states adopted by these switches and for undertaking predetermined actions as a result of a change thereof, are therefore required to monitor these states continuously.

[0005] Information regarding the instantaneous state of a switch is generally acquired by the provision of a network (for example, this may simply be a resistive divider) which supplies the switch and which detects the voltage established at the terminals of the switch and compares its value with one or more threshold values.

[0006] It is well known that an electrical switch has a very high (theoretically infinite) equivalent resistance in an open state and an almost zero equivalent resistance in a closed state.

[0007] Switches fitted in motor vehicles are generally exposed to moisture, dirt and other atmospheric agents with the result that they undergo damage to their contacts and, in some cases, exhibit a general malfunction condition. For example, an electrical switch which in an open state would have an equivalent resistance of the order of 100 kΩ or more may have a greatly reduced equivalent resistance (of the order of a few kΩ) because an undesired current path is established between the contacts. There is therefore a risk of confusing an open state with a closed state and interpreting the presence of commands which have never actually been given.

[0008] To prevent problems of this type, typically, it is necessary to apply to the contacts of the switch a high-intensity current (a so-called cleaning current) which enables an open or closed state of the switch to be recognized correctly, even in conditions of excessive damage to its contacts.

[0009] At the moment, in automotive applications, a method is used in which each switch is constantly supplied with a cleaning current of considerable intensity and the value of the voltage which is established at its terminals is transferred to the input of a processing and control unit where it is converted into a digital signal and stored.

[0010] However, this method does not permit quantitative diagnosis of a condition of damage to the contacts of the switch, that is, it cannot recognize whether a certain voltage value at the terminals of the switch results from a corresponding actual operative state or from a condition of excessive damage.

[0011] Moreover, this method seems expensive since it requires the use of complex processing and control units having one or more A/D converters.

[0012] In all of these cases it would instead be preferable, in the absence of events, for the control unit to operate in an operative state of low current consumption, for example, in order not to discharge the battery of the vehicle, but to be able to recognize correctly the operative state of a switch and/or a possible malfunction condition thereof.

[0013] The object of the present invention is therefore to provide a satisfactory solution to the problems set out above, preventing the problems of the prior art. According to the present invention, this object is achieved by means of a circuit having the characteristics recited in Claim 1.

[0014] In summary, the present invention is based on the principle of supplying the switches continuously with a monitoring current of low intensity so as to satisfy the requirements of low consumption and, selectively, in dependence on the detection of a presumed change in the state of a switch, with a diagnosis current of greater intensity in order to check that the event has actually occurred or to reveal a condition of damage to the switch.

[0015] The supply of the monitoring current permits continuous monitoring of the state of a switch and qualitative recognition of cases in which the switch has a low or almost zero equivalent resistance (and hence a voltage below a first predetermined threshold value at its terminals) or a very high equivalent resistance (and hence a voltage above a second predetermined threshold value at its terminals).

[0016] Since, as stated above, a low or almost zero equivalent resistance may be due to the closed state of the switch, but also to a condition of damage thereto which is present in an open state, when the control unit recognizes that this situation has arisen, the control unit is arranged to supply the diagnosis current and to take a further reading of the state of the switch.

[0017] The network for supplying the switches includes, for each switch, a pair of circuit branches, each of which is supplied by a corresponding supply voltage and which, in the currently-preferred embodiment, constitute, with the switches, resistive dividers.

[0018] The supply voltages and the resistive components of these branches are advantageously selected in a manner such that, for a equivalent resistance value which is typical of a condition of damage to the switch so that this condition is interpreted as a closed state of the switch when it is supplied solely with the monitoring current, the supply by means of the diagnosis current

enables the open state of the switch to be detected correctly, thus giving rise to two different readings.

[0019] The supply voltages and the resistive components of the supply network are also advantageously selected in a manner such that the closed state of a switch and the open state in an undamaged condition are interpreted in the same manner in both supply situations.

[0020] The control unit is then arranged to warn the user of the vehicle of the appearance of a malfunction condition when there are differing readings, and to undertake cyclically a checking procedure to ascertain whether a correct operating condition has been re-established.

[0021] Further characteristics and advantages of the invention will be explained in greater detail in the following detailed description of an embodiment thereof, given by way of non-limiting example, with reference to the appended drawings, in which:

Figure 1 is an electrical diagram of a circuit according to the invention;

Figure 2 shows the equivalent circuit of a switch;

Figure 3a is a table indicating qualitatively the logic levels of the signals indicative of the state of a switch when the switch is supplied by a monitoring current; and

Figure 3b is a table indicating qualitatively the logic levels of the signals indicative of the state of a switch when the switch is supplied by a diagnosis current.

[0022] The electrical switches are indicated SW_i (i = 1, 2, ..., n) and Figure 1 in particular shows two switches, indicated SW_1 and SW_2, respectively. A first terminal is connected to a respective node N_i (i = 1, 2, ..., n) of a supply network and a second terminal is connected to earth.

[0023] The switches are also connected to a microprocessor control unit P via respective connection lines, for example, for the switches SW_1 and SW_2, the lines 10, 20 each of which is connected at one end to the corresponding node N_i and at the other end to an activation input IRQ_i and to a reading input RD_i of the control unit P.

[0024] The supply network includes first and second circuit branches connected to each switch via the respective node N_i and supplied by means of corresponding terminals VS_1 and VS_2, respectively.

[0025] The structure of these circuit branches will be described below with reference solely to the switch SW_1, upon the understanding that this structure is repeated for every other switch present.

[0026] A first supply circuit branch B_1, to the supply terminal VS_1 of which a first supply voltage V_{cc} is applied, comprises a resistor R_1 interposed between the supply terminal and the node N_1.

[0027] A second supply circuit branch B_2 to the supply terminal VS_2 of which a second supply voltage V_B is selectively applied, comprises a resistor R_2 and a diode D connected in series therewith, with its cathode connected to the node N_1. The supply terminal VS_2 is connected to a battery B (for example, the 12V battery of the vehicle, in automotive applications) by means of the emitter-collector path of a switch Q. A single switch Q is common to all of the second circuit paths B_2 and is formed by a bipolar transistor the base terminal of which is connected to an output EN of the control unit P.

[0028] The presence of the diode is justified by the need to prevent undesired current paths being established between circuit branches of different switches. With reference to Figure 1, for example, the connection of the diodes D in the branches B_2 prevents the monitoring current supplied to the switch SW_2 from flowing from the respective branch B_1, through the respective branch B_2 and the branch B_2 relating to SW_1, towards the switch SW_1, upon closure of the switch SW_1, confusing the reading of the voltage at the node N_1.

[0029] For a better understanding of the operation of the circuit of the invention, the equivalent circuit of an electrical switch SW_i is described below with reference to Figure 2.

[0030] An electrical switch approximates to the behaviour of an ideal switch SW_{id} (short-circuit in a closed state, open circuit in an open state), except for a resistive component in series, indicated R_s, which intervenes in a closed state and is of the order of a few tens of ohms (the value typically recognized for an on/off switch or a diverter switch for applications in the automotive field is 25Ω), and except for a resistive component in parallel, indicated R_p which takes account of any parasitic current path between the contacts of the switch due to conditions of wear and dirtiness.

[0031] In an electrical switch which is in good condition, the contacts of which are not dirty or worn, the resistive component R_p in parallel is of the order of hundreds of kΩ; in a damaged switch, the value typically recognized for the resistive component R_p is 2kΩ.

[0032] When the switch is in a closed state, the equivalent resistance exhibited is thus given by the components R_s and R_p in parallel, that is, it again approximates to the value of the resistive component R_s in series. In an open state, only the resistive component R_p, the value of which may vary by a few orders of magnitude according to the condition of damage to the contacts, becomes significant.

[0033] By way of reference, in dependence on the values of the resistive components considered in the model of the actual switch referred to above, the supply voltage V_{cc} applied to the terminal VS_1 of the first circuit branch is preferably 5V (and corresponds to the supply voltage of the control unit P), whereas the supply voltage V_B applied selectively to the terminal VS_2 of the second circuit branch is derived directly from the battery B (and is therefore about 12V). The values of the resistors R_1 and

R_2 are preferably 47kΩ and 1kΩ, respectively.

[0034] In the currently-preferred embodiment, the signal indicative of the state of a switch is acquired by detecting the voltage which is established at its terminals.

[0035] When the control unit P is awaiting an event, the switch Q is non-conductive and each switch SW_i is supplied with a monitoring current exclusively via the respective first circuit branch B_1. The control unit P is therefore able to monitor the (normally open) state of each switch continuously, operating in a state of low current consumption (of the order of hundredths of a mA).

[0036] The voltage detected at the node N_i is determined by the resistive divider constituted by the resistor R_1 and by the equivalent resistance of the switch.

[0037] The equivalent resistance of a closed switch adopts a value substantially equal to R_s (almost zero) and the voltage at the corresponding node N_i adopts a value close to the earth potential and in any case within a first range of values or below a predetermined first threshold value. The control unit P receives this voltage value at the corresponding input IRQ_i and interprets it as a low logic level binary signal. A monitoring current of the order of a tenth of a mA flows through the switch.

[0038] For an open switch in good condition, the equivalent resistance R_p is of the order of hundreds of kΩ or more and the supply voltage V_{cc} is divided and is established predominantly at the terminals of the switch.

[0039] The voltage at the corresponding node N_i adopts a value within a second range of values or above a predetermined second threshold value. The control unit P receives this voltage value at the corresponding input IRQ_i and interprets it as a high logic level binary signal.

[0040] The establishment of a low logic level signal at an input IRQ_i of the control unit P brings about activation thereof and reading of the signal by means of a respective reading input RD_i.

[0041] A situation of this type also arises when a switch undergoes excessive damage to its contacts and its equivalent resistance R_p in the open state adopts a low value (of the order of 2 kΩ) much lower than R_1. The supply voltage V_{cc} is divided and is established predominantly at the terminals of R_1 and, although the voltage at the node N_i is not close to the earth potential, it nevertheless adopts a value within the first range of values or below the first threshold value, which is again interpreted as a low logic level binary signal.

[0042] Every time the control unit is activated, it is arranged to take a further reading of the state of the switch in order to distinguish which event has actually occurred.

[0043] It sends a consent signal to the switch Q, by means of the output EN, in order to make the switch Q conductive and to supply the switches SW_i with a diagnosis current of greater intensity than the monitoring current, via the respective second circuit branches B_2.

[0044] The voltage detected at the node N_i is now determined substantially by the resistive divider constituted by the emitter-collector path of the switch Q, by the resistor R_2, by the diode D polarized directly, and by the equivalent resistance of the switch. A diagnosis current of the order of a few mA flows through the switch.

[0045] For an open but excessively damaged switch, the equivalent resistance R_p is of the order of one kΩ, but is still comparable with R_2 so that the supply voltage V_B is divided and is established predominantly at the terminals of the switch and the voltage at the corresponding node N_i again adopts a value within the second range of values or above the second threshold value, and the control unit interprets this value correctly as a high logic level binary signal.

[0046] In this case, the readings of the state of the switch taken at two distinct moments as a result of the supply of the monitoring current and of the diagnosis current give different results and the control unit P recognizes the condition of malfunction of the switch.

[0047] If the switch is actually closed, the readings are the same and the control unit correctly recognizes the closed state of the switch and undertakes the predetermined actions resulting from this event.

[0048] The possible combinations of logic levels of the signals at the inputs IRQi in dependence on the state and the conditions of the switches are summarized in Figures 3a and 3b.

[0049] If the control unit has detected a general condition of malfunction of a switch, it warns the user of the vehicle of this condition and is arranged to perform cyclically a checking procedure to ascertain whether a correct operating condition has been re-established.

[0050] At a first moment, the control unit prevents the supply of the diagnosis current, arranging the network for supplying the switches to operate with the monitoring current alone (switch Q non-conductive). Cyclically, after a waiting period of predetermined duration, it reads the states of the switches at two successive moments by supplying them by means of the monitoring current and by means of the diagnosis current, respectively.

[0051] If the readings differ, the persistence of the malfunction condition is recognized and the unit is arranged for a further diagnosis when a subsequent waiting period has elapsed.

[0052] If similar readings are finally detected, for example, because the contacts of the damaged switch have been cleaned or the worn switch has been replaced, the unit advantageously starts to operate in the normal operative condition again, and is set to await an event (supply with low current consumption).

[0053] Naturally, the principle of the invention remaining the same, the forms of embodiment and details of construction may be varied widely with respect to those described and illustrated purely by way of non-limiting example, without thereby departing from the scope of protection of the present invention.

[0054] This applies in particular to the possibility of using a microprocessor in which the activation inputs IRQ_i and the reading inputs RD_i coincide, or the possibility of

varying the values for the supply voltage and the resistances of the circuit branches indicated in the foregoing discussion.

[0055] More generally, moreover, the invention is not limited purely to the preferred embodiment described fully by way of example, in which the signal indicative of the state of a switch is acquired by detecting the voltage at the terminals of the switch, but further embodiments in which this signal is acquired at other points of the circuit branches for supplying the switches are also envisaged.

[0056] Further embodiments having alternative arrangements to those described for the generation of the monitoring current and of the diagnosis current in the circuit branches associated with the switches are also included within the scope of protection of the present invention.

Claims

1. A circuit for detecting the state of electrical switches, for example, switches (SW_i) in a motor vehicle, comprising:

   - a network (B_1, B_2) which supplies the switches (SWi) and which is adapted to produce signals indicative of the operative state of each switch (SW_i); and

   - a control unit (P) which is associated with the switches (SW_i), adapted to receive the signals indicative of the state of each switch (SW_i) at respective inputs (RD_i), and arranged to undertake corresponding predetermined actions in dependence on said signals,

   characterized in that the supply network comprises, associated with each switch (SW_i) :

   - a respective first circuit branch (B_1) arranged for continuously supplying a monitoring current as a result of which a first signal indicative of the state of the switch (SW_i) is produced, and

   - a respective second circuit branch (B_2) arranged for supplying, in dependence on a consent signal, a diagnosis current of greater intensity than the monitoring current, as a result of which a second signal indicative of the state of the switch (SW_i) is produced,

   and in that the control unit (P) is adapted to interpret the first and second signals in accordance with a binary logic and is arranged:

   to generate the consent signal each time it receives, at at least one input (RD_i), a first signal indicative of a presumed closed state of a switch (SW_i);

   to detect at least one second signal indicative of the state of a corresponding switch (SW_i) when the switch (SW_i) is supplied with the diagnosis current;

   to compare the values of the first signal and of the second signal and to interpret the state of the switch (SW_i) as the closed state when the values are the same and as the open state in a malfunction condition when the values differ.

2. A circuit according to Claim 1, characterized in that a first supply voltage (V_{cc}) is applied to each first branch (B_1), and a second supply voltage (V_B) is applied selectively to each second branch (B_2), and in that the branches (B_1; B_2) have substantially resistive characteristics.

3. A circuit according to Claim 2, characterized in that each first branch (B_1) and each second branch (B_2) and the corresponding switch (SW_i) bring about a division of the first supply voltage (V_{cc}) and of the second supply voltage (V_B), respectively, such that, in an open state of the switch (SW_i) and in a malfunction condition,

   the first signal indicative of the operative state of the switch (SW_i) has a voltage which adopts a value within a first range of values corresponding to a first logic level; and

   the second signal has a voltage which adopts a value within a second range of values corresponding to a second logic level.

4. A circuit according to Claim 3, characterized in that the first and second signals indicative of the state of a switch are acquired at the terminals of the switch (SW_i).

5. A circuit according to any one of the preceding claims, characterized in that the supply network (B_1, B_2) comprises switching means (Q) which are associated with the second branches (B_2) and which can be driven by the consent signal in order to apply the second supply voltage (V_B) selectively to the branches (B_2).

6. A circuit according to Claim 5, characterized in that the switching means (Q) comprise a bipolar transistor.

7. A circuit according to any one of the preceding claims, characterized in that each second branch (B_2) comprises a unidirectional conduction element

(D).

8. A circuit according to any one of the preceding claims, characterized in that the control unit (P) has, for each switch (SW_i), an activation input (IRQ_i) and a reading input (RD_i) for the acquisition of the signals indicative of the state of the switch (SW_i).

9. A circuit according to any one of the preceding claims, characterized in that, in the event of a malfunction condition arising in a switch, the control unit (P) is arranged to indicate the malfunction condition to a user.

10. A circuit according to any one of the preceding claims, characterized in that the control unit (P) is arranged to undertake a cyclical checking procedure as a result of the detection of a malfunction condition, the procedure comprising the steps of:

    checking the elapse of a predetermined waiting period in an operative condition in which the switches (SW_i) are supplied by the monitoring current;

    detecting a first signal indicative of the state of the switch (SW_i) when the period has elapsed;

    generating the consent signal for the supply of the switches (SW_i) with the diagnosis current;

    detecting a second signal indicative of the state of the switch (SW_i); and

    comparing the values of the first signal and of the second signal,

    the control unit recognizing the persistence of the malfunction condition when the values of the first signal and of the second signal are different and a re-established correct operating condition when the said values are the same.

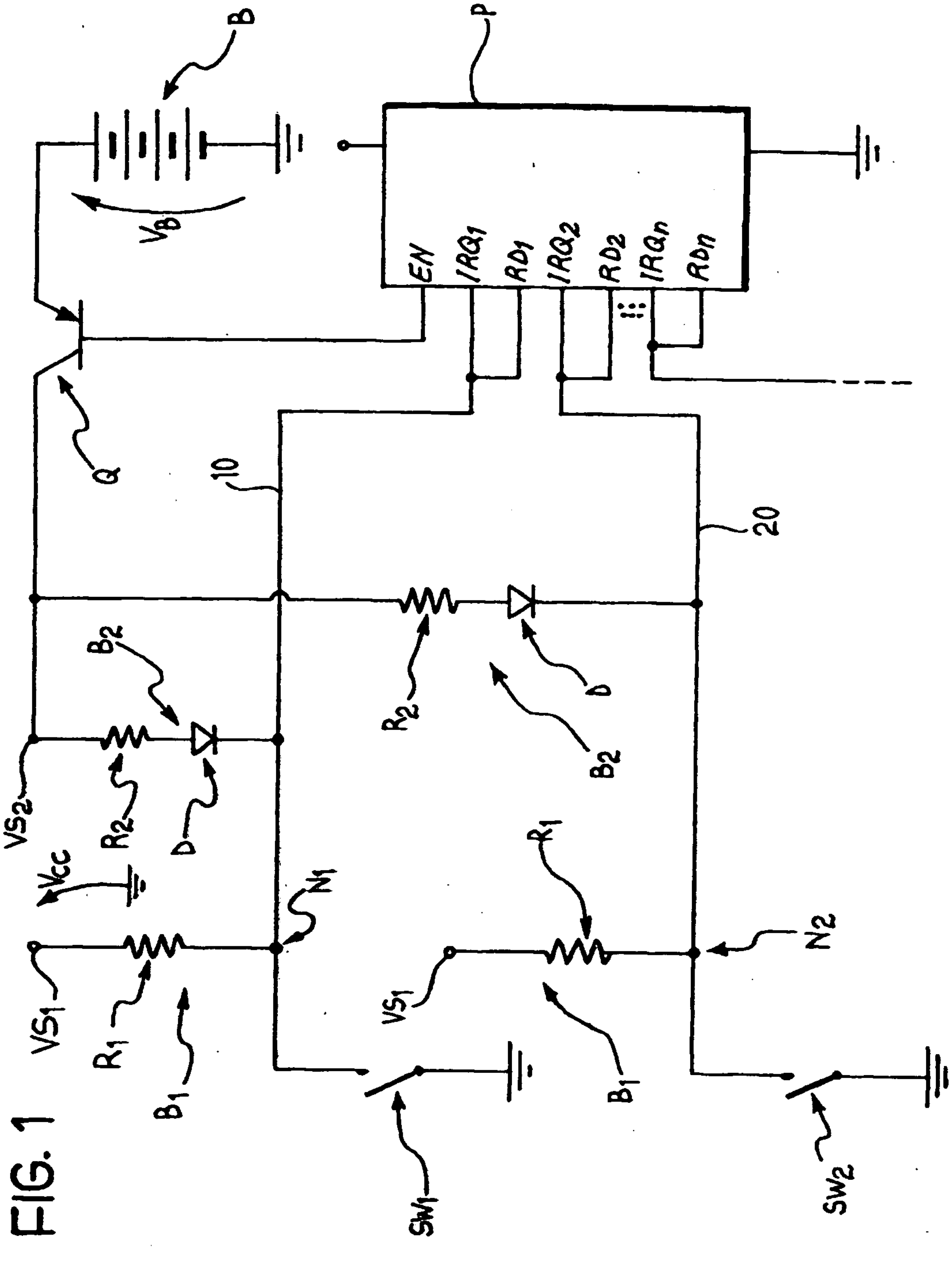
B
P
V_B
EN
IRQ_1
RD_1
IRQ_2
RD_2
IRQ_n
RD_n
Q
10
20
B_2
R_2
D
VS_2
Vcc
VS_1
R_1
B_1
N_1
N_2
SW_1
SW_2

FIG. 1

FIG. 2

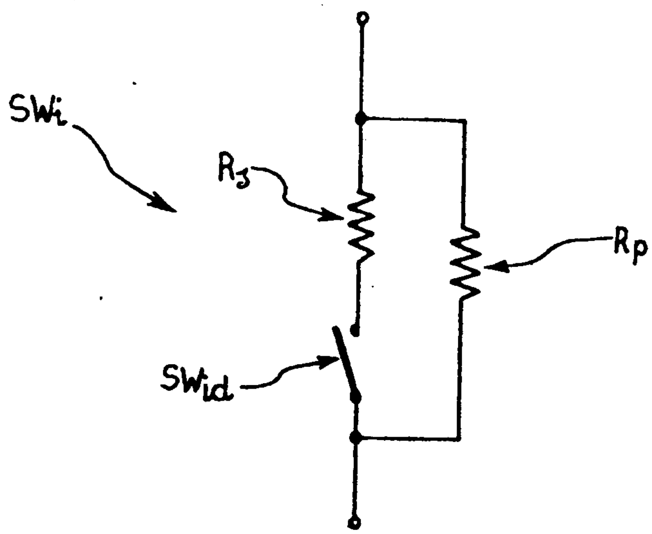

FIG. 3a

	UNDAMAGED	DAMAGED
SWi OPEN	HIGH	LOW
SWi CLOSED	LOW	LOW

RDi

FIG. 3b

	UNDAMAGED	DAMAGED
SWi OPEN	HIGH	HIGH
SWi CLOSED	LOW	LOW

RDi

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EUROPEAN SEARCH REPORT

Application Number
EP 00 12 4515

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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	16 February 2001	Durand, F

CATEGORY OF CITED DOCUMENTS

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